WHAT IS CLAIMED IS:

1. A method for designing a vehicle suspension system, comprising:

formalizing the vehicle suspension system by an equation (1), the vehicle suspension system including a plurality of springs, a plurality of dampers each corresponding to one of the springs, and a plurality p of actuators, equation (1) being a linear matrix equation having a number, n, degrees of freedom, the linear matrix equation including a damping matrix for viscous damping;

calculating eigenvectors of a stiffness matrix K of equation (1);

normalizing the eigenvectors with respect to a mass matrix M of equation (1);

calculating a similarity transform matrix S consisting of the normalized eigenvectors; and

normalizing equation (1) using the similarity transform matrix S, wherein equation (1) is

$$M\ddot{x}(t) + C(\dot{x}(t) - \dot{u}(t)) + K(x(t) - u(t)) = Pf(t)$$

wherein:

n and p respectively denote the degrees of freedom of the suspension system and the number of independent actuators;

M, C, and K respectively denote a mass matrix, a damping matrix, and a stiffness matrix, each of which is symmetrically n×n, the mass matrix M being a positive definite matrix, the damping matrix C being a positive semi-definite matrix, and the stiffness matrix K being a positive definite matrix;

P denotes an n×p real matrix corresponding to positions of the actuators,

$x(t)$ and $u(t)$ respectively denote n×1 state and disturbance vectors; and

$f(t)$ denotes a p×1 external force vector.

2. The method of claim 1, wherein the normalizing equation (1) establishes a proportional relationship $k_j = \alpha \times c_j$ between each pair of a spring coefficient k_j of a j-th spring and a damping coefficient c_j of a j-th damper corresponding to the j-th spring.

3. A vehicle suspension system comprising:

a plurality of springs;

a plurality of dampers, each corresponding to one of the springs; and

a plurality p of actuators for generating control force to the suspension system, wherein:

the suspension system is formalized by an equation (1); and

equation (1) is decoupled into n modal equations,

wherein equation (1) is a linear matrix equation having a plurality n of degrees of freedom, and the linear matrix equation includes a damping matrix for a viscous damping,

wherein equation (1) is

$$M\ddot{x}(t)+C\left(\dot{x}(t)-\dot{u}(t)\right)+K\left(x(t)-u(t)\right)=Pf(t)$$

wherein:

n and p respective denote the degrees of freedom of the suspension system and the number of independent actuators;

M, C, and K respectively denote a mass matrix, a damping matrix, and a stiffness matrix, each of which is symmetrically n×n, the mass matrix M being a positive definite matrix, the damping matrix C being a positive semi-definite matrix, and the stiffness matrix K being a positive definite matrix;

P denotes an n×p real matrix corresponding to positions of the actuators,

$x(t)$ and $u(t)$ respectively denote n×1 state and disturbance vectors; and

$f(t)$ denotes p×1 external force vector.

4. The vehicle suspension system of claim 3, wherein a proportional relationship $k_j = \alpha \times c_j$ is satisfied between each pair of a spring coefficient k_j of a j-th spring and a damping coefficient c_j of a j-th damper corresponding to the j-th spring.

5. The vehicle suspension system of claim 4, wherein the number n and the number p are equal,

the suspension system further comprising:

a detecting unit for detecting at least one of the state vector $x(t)$ and its velocity $\dot{x}(t)$; and

a controller for controlling the actuators on the basis of the detected one of the state vector $x(t)$ or its velocity $\dot{x}(t)$,

wherein the controller controls the actuators by an actuating force of $f = Q^{-1}\hat{f}$,

wherein:

$Q = S^T P$, $\hat{f}_i = -C_{Si}\dot{\xi}_i$, and $x(t) = S\,\xi(t)$ are satisfied;

C_{Si} is a damping coefficient of a sky-hook damper connected to an i-th mode; and

S is a matrix consisting of eigenvectors of the stiffness matrix K and is normalized with respect to the mass matrix M.

6. The vehicle suspension system of claim 4, wherein the number p is less than the number n,

the suspension system further comprising:

a detecting unit for detecting at least one of the state vector $x(t)$ and its velocity $\dot{x}(t)$; and

a controller for controlling the actuators on the basis of the detected one of the state vector $x(t)$ or its velocity $\dot{x}(t)$,

wherein the controller controls the actuators by an actuating force of $f(t)$ that satisfies $\hat{f}_i = -F_{Si}sign(\dot{\xi}_i) = \sum_{j=1}^{p} Q_{ij} f_j$,

wherein:

$Q = S^T P$ and $x(t) = S\,\xi(t)$ are satisfied;

F_{Si} is a frictional force of a sky-hook coulomb friction damper connected to an i-th mode; and

S is a matrix consisting of eigenvectors of the stiffness matrix K and is normalized with respect to the mass matrix M.

7. The vehicle suspension system of claim 6, wherein the actuating force $f(t)$ satisfies

$$\begin{Bmatrix} if\ Q_{1j}sign(\dot{\xi}_1)\geq 0 \& Q_{2j}sign(\dot{\xi}_2)\geq 0 \& \cdots Q_{nj}sign(\dot{\xi}_n)\geq 0, & f_j=-F_A \\ if\ Q_{1j}sign(\dot{\xi}_1)\geq 0 \& Q_{2j}sign(\dot{\xi}_2)\geq 0 \& \cdots Q_{nj}sign(\dot{\xi}_n)< 0, & f_j=-F_1 \\ \vdots & \vdots \\ if\ Q_{1j}sign(\dot{\xi}_1)< 0 \& Q_{2j}sign(\dot{\xi}_2)< 0 \& \cdots Q_{nj}sign(\dot{\xi}_n)\geq 0, & f_j=-F_{(2^n-2)} \\ if\ Q_{1j}sign(\dot{\xi}_1)< 0 \& Q_{2j}sign(\dot{\xi}_2)< 0 \& \cdots Q_{nj}sign(\dot{\xi}_n)< 0, & f_j=-F_B \end{Bmatrix}$$

with respect to $i=1,\ldots,n$ and $j=1,\ldots,p$,

wherein:

F_A is a value in a range of zero(0) to F_P;

F_B is a value in a range of zero(0) to F_N;

F_k for $k=1,\ldots,(2^n-2)$ is a value between F_P and F_N; and

F_P and F_N respectively denote a positive maximum force and a negative maximum force that a j-th actuator can generate.

8. The vehicle suspension system of claim 7, wherein the actuating force $f(t)$ satisfies

$$\begin{Bmatrix} if\ Q_{ij}sign(\dot{\xi}_i)\geq 0\ \ for\ i=1,\ldots,n, & f_j=-F_A \\ if\ Q_{ij}sign(\dot{\xi}_i)< 0\ \ for\ i=1,\ldots,n, & f_j=-F_B \\ Otherwise, & f_j=0 \end{Bmatrix}$$

with respect to $i=1,\ldots,n$ and $j=1,\ldots,p$.

9. The vehicle suspension system of claim 8, wherein values of F_A and F_P are equal, and values of F_B and F_N are equal.

10. A method for controlling a vehicle suspension system, the vehicle suspension including a plurality of dampers and a plurality of actuators, the vehicle suspension system being formalized by an equation (1) and being transformed to a decoupled equation (2), the method comprising:

calculating a velocity vector $\dot{x}(t)$ of a state vector $x(t)$ of equation (1);

calculating an actuating force $f(t)$ such that the actuating force $f(t)$ satisfies $f(t)=(S^T P)^{-1}(-C_{Si})(S^T KS)^{-1}(S^T K)\dot{x}(t)$, the C_{Si} being a damping coefficient of a sky-hook damper connected to an i-th mode; and

actuating the actuators by the calculated actuating force $f(t)$,

wherein:

equation (1) is

$$M\ddot{x}(t)+C\big(\dot{x}(t)-\dot{u}(t)\big)+K\big(x(t)-u(t)\big)=Pf(t)$$, and

equation (2) is

$$I\ddot{\xi}(t)+diag[2\zeta_i\omega_i]\big(\dot{\xi}(t)-\dot{\eta}(t)\big)+\Lambda_K\big(\xi(t)-\eta(t)\big)=\hat{f}(t)$$

wherein:

n and p respective denote the degrees of freedom of the suspension system and the number of independent actuators;

M, C, and K respectively denote a matrix, a damping matrix, and a stiffness matrix, each of which is symmetrically n×n, the mass matrix M being a positive definite matrix, the damping matrix C being a positive semi-definite matrix, and the stiffness matrix K being a positive definite matrix;

P denotes an n×p real matrix corresponding to positions of the actuators,

$x(t)$ and $u(t)$ respectively denote n×1 state and disturbance vectors;

$f(t)$ denotes a p×1 external force vector;

I is an n×n unit matrix;

S is a matrix consisting of eigenvectors of the stiffness matrix K and is normalized with respect to the mass matrix M; and

$Q = S^T P$, $\hat{f} = Qf(t)$, $x(t) = S\,\xi(t)$, $u(t) = S\eta(t)$, $S^T KS = diag[\omega_i^{\ 2}] = \Lambda_K$, and $S^T CS = \hat{C} = diag[2\zeta_i \omega_i]$ are satisfied by the matrix S.

11. A method for controlling a vehicle suspension system, the vehicle suspension including a plurality of dampers and a plurality of actuators, the vehicle suspension system being formalized by an equation (1) and being transformed to a decoupled equation (2), the method comprising:

calculating a velocity vector $\dot{x}(t)$ of a state vector $x(t)$ of equation 1;

calculating an actuating force $f(t)$ such that the actuating force $f(t)$ satisfies

$$\begin{Bmatrix} if\, Q_{1j} sign(\dot{\xi}_1) \geq 0 \& Q_{2j} sign(\dot{\xi}_2) \geq 0 \& \cdots Q_{nj} sign(\dot{\xi}_n) \geq 0, & f_j = -F_A \\ if\, Q_{1j} sign(\dot{\xi}_1) \geq 0 \& Q_{2j} sign(\dot{\xi}_2) \geq 0 \& \cdots Q_{nj} sign(\dot{\xi}_n) < 0, & f_j = -F_1 \\ \vdots & \vdots \\ if\, Q_{1j} sign(\dot{\xi}_1) < 0 \& Q_{2j} sign(\dot{\xi}_2) < 0 \& \cdots Q_{nj} sign(\dot{\xi}_n) \geq 0, & f_j = -F_{(2^n-2)} \\ if\, Q_{1j} sign(\dot{\xi}_1) < 0 \& Q_{2j} sign(\dot{\xi}_2) < 0 \& \cdots Q_{nj} sign(\dot{\xi}_n) < 0, & f_j = -F_B \end{Bmatrix}$$

with respect to $i = 1, \ldots n$ and $j = 1, \ldots, p$; and

actuating the actuators by the calculated actuating force $f(t)$,

wherein:

F_A is a value in a range of zero (0) to F_P;

F_B is a value in a range of zero (0) to F_N;

F_k for $k = 1, \ldots, (2^n - 2)$ is a value between F_P and F_N;

F_P and F_N respectively denote a positive maximum force and a negative

maximum force that a j-th actuator can generate;

equation (1) is

$$M\ddot{x}(t) + C(\dot{x}(t) - \dot{u}(t)) + K(x(t) - u(t)) = Pf(t)$$; and

equation (2) is

$$I\ddot{\xi}(t) + diag[2\zeta_i\omega_i](\dot{\xi}(t) - \dot{\eta}(t)) + \Lambda_K(\xi(t) - \eta(t)) = \hat{f}(t)$$

wherein:

n and p respective denote the degrees of freedom of the suspension system and the number of independent actuators;

M, C, and K respectively denote a mass matrix, a damping matrix, and a stiffness matrix, each of which is symmetrically n×n, the mass matrix M being a positive definite matrix, the damping matrix C being a positive semi-definite matrix, and the stiffness matrix K being a positive definite matrix;

P denotes an n×p real matrix corresponding to positions of the actuators,

$x(t)$ and $u(t)$ respectively denote n×1 state and disturbance vectors;

$f(t)$ denotes a p×1 external force vector;

I is an n×n unit matrix;

S is a matrix consisting of eigenvectors of the stiffness matrix K and is normalized with respect to the mass matrix M; and

$Q = S^T P$, $\hat{f} = Qf(t)$, $x(t) = S\,\xi(t)$, $u(t) = S\eta(t)$, $S^T KS = diag[\omega_i^2] = \Lambda_K$, and $S^T CS = \hat{C} = diag[2\zeta_i\omega_i]$ are satisfied by the matrix S.

12. The method of claim 11, wherein the actuating force $f(t)$ satisfies

$$\begin{Bmatrix} if\ Q_{ij}sign(\dot{\xi}_i) \geq 0 \ \ for\ i = 1,\ldots,n, & f_j = -F_A \\ if\ Q_{ij}sign(\dot{\xi}_i) < 0 \ \ for\ i = 1,\ldots,n, & f_j = -F_B \\ Otherwise, & f_j = 0 \end{Bmatrix}$$

with respect to $i = 1,\ldots,n$ and $j = 1,\ldots,p$.

13. The method of claim 12, wherein values of F_A and F_P are equal, and values of F_B and F_N are equal.